

SPECIFICATION

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COUNTER-FLOW HEAT EXCHANGER FOR CERAMIC GAS GENERATOR

Cross Reference to Related Applications

This application claims the benefit of U.S. Provisional Application Serial No. 60/319,491, filed August 25, 2002, entitled COUNTER-FLOW HEAT EXCHANGER FOR CERAMIC GAS GENERATOR.

Background of Invention

[0001] 1. Technical Field

[0002] The invention relates to the field of fuel cells and ceramic oxygen generators, and more particularly to heat exchangers for recovering heat from such devices.

[0003] 2. Background Art

[0004] In one embodiment of a ceramic oxygen generating device, a solid-state process is used to separate oxygen from atmospheric air for medical use. The ceramic electrolyte used in this process is maintained at a temperature of approximately 600 ° C or higher for the ionic transport mechanism to operate efficiently. For these gas separation devices to operate efficiently and safely, heat losses from the system must be minimized.

[0005] One of the most significant potential heat losses from the system is the heat lost in the furnace exhaust air stream. Air entering the ceramic generating furnace must be raised to a temperature very close to the furnace operating temperature prior to coming in contact with the ceramic generating modules. For example, with a furnace temperature of 750 ° C and an ambient temperature of 25 ° C, each liter per minute of

air flowing through the furnace requires approximately 14.5 Watts of heat input to get up to temperature. Then a furnace requiring 50 liters per minute of airflow would require approximately 725 Watts heat input just to raise the air stream to operating temperature under these conditions.

[0006] In addition, the hot air stream exiting the furnace can not simply be vented to the environment due to the extreme personal safety and fire hazard it would present. A substantial portion of the heat carried by the exhaust air stream must be removed by some means before it may be safely returned to the environment. With a 50 liter per minute furnace airflow, one Watt of cooling power would be required reduce the exhaust stream temperature by 1 ° C.

[0007] U.S. Patent No. 6,379,878, issued April 16, 2002 to Dean et al. teaches a fuel cell system including a heat recovery system that transfers some of the heat from the exhaust stream to an input stream.

[0008] Similarly, U.S. Patent No. 6,382,958, issued May 7, 2002 to Bool, III et al. discloses an oxygen separator system that includes a heat exchanger.

[0009] While the above cited references introduce and disclose a number of noteworthy advances and technological improvements within the art, none completely fulfills the specific objectives achieved by this invention.

Summary of Invention

[0010] In accordance with the present invention, a heat exchanger for ceramic oxygen generating systems, fuel cells, or the like, that have a heat generating furnace, includes at least one heat exchanging arm that is formed from an inner and an outer concentric tube. The heat exchanger arm has an inner and outer passageway that is separated by a common wall that comprises the inner concentric tube.

[0011] The inner concentric tube has a first end with a fluid flow outlet for discharging an exhaust fluid and a second end with a fluid flow inlet for receiving an input of the exhaust fluid. Similarly, the outer concentric has a first end with a fluid flow inlet for receiving an input of an intake fluid flow and a second end with a fluid flow outlet for discharging the intake fluid. The exhaust fluid flows through the inner concentric tube

in a direction substantially opposite to the intake fluid flow through the heat exchanger arm. Note that the intake and exhaust fluids can be reversed if desired. In the preferred embodiment the cooler fluid flows through the outermost tube to further improve the overall efficiency of the heat exchanger.

[0012] The inner and outer concentric tubes in a preferred embodiment form rectangular channels to maximize the surface area of the common walls to increase surface area for heat transfer.

[0013] These and other objects, advantages and features of this invention will be apparent from the following description taken with reference to the accompanying drawings, wherein is shown the preferred embodiments of the invention.

Brief Description of Drawings

[0014] A more particular description of the invention briefly summarized above is available from the exemplary embodiments illustrated in the drawing and discussed in further detail below. Through this reference, it can be seen how the above cited features, as well as others that will become apparent, are obtained and can be understood in detail. The drawings nevertheless illustrate only typical, preferred embodiments of the invention and are not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

[0015] Figure 1 is an isomeric view of a counter-flow heat exchanger of the present invention.

[0016] Figure 2 is a perspective view of a heat exchanger integrated with a furnace of a ceramic oxygen generating system.

[0017] Figure 3 is a cross-sectional view taken along line 3-3 of Figure 2.

[0018] Figure 4 is another embodiment of the heat exchanger of the present invention.

[0019] Figure 5 is an end view of the heat exchanger of Figure 4 taken in the direction of arrow 5.

Detailed Description

[0020] So that the manner in which the above recited features, advantages, and objects of the present invention are attained can be understood in detail, more particular description of the invention, briefly summarized above, may be had by reference to the embodiment thereof that is illustrated in the appended drawings. In all the drawings, identical numbers represent the same elements.

[0021] One obvious solution to both heat problems describe above is to "recycle" or transfer some of the heat from the exhaust air stream and feed it back into the inlet air stream. Similar heat recycling practices have been common in commercial electrical generating stations for many years. Each watt of heat recovered from the exhaust air stream directly results in a watt power saving for the furnace heaters and a watt less of auxiliary cooling required for the exhaust air stream. A very effective way to accomplish this is by use of an air-to-air heat exchanger. However, many typical commercial heat exchangers, especially of the cross-flow type, are both bulky and heavy.

[0022] Heat exchanger theory indicates that high thermal effectiveness may be achieved using a counter-flow heat exchanger design. Originally, a simple concentric-tube counter-flow heat exchanger was considered for this application. Tests of a concentric tube design heat exchanger suggested that a concentric tube design was incapable of achieving the required thermal effectiveness within a constraints envelope for the oxygen generating system.

[0023] It is also well known that performance advantages result from employing narrow rectangular flow channels (with an aspect ratio greater than 8:1) rather than circular ones (or rectangular ones with an aspect ratio closer to 1:1) for a heat exchanger. For the initial heat exchanger design, the flow areas of both passes were optimized based on the anticipated thermal effectiveness to balance the pressure loss between the two passes. A potential drawback to this thin rectangular geometry is that the pressure drop may be somewhat greater than for a round tube with the same flow area.

[0024] A heat exchanger (E) for ceramic oxygen generating systems, fuel cells, or the like that have a heat generating furnace (F) to provide heat to an internally mounted oxygen separator or other operable component requiring a heated environment. The heat exchanger (E) includes at least one heat exchanging arm (10) that is formed from

an inner (12) and an outer (14) concentric tube. The heat exchanger arm (10) has an inner (16) and outer (18) passageway that is separated by a common wall (20) that comprises the inner concentric tube (12).

[0025] The inner concentric tube (12) has a first end (22) with a fluid flow outlet (24) for discharging an exhaust fluid (26) and a second end (28) with a fluid flow inlet (30) for receiving an input (32) of the exhaust fluid (26). Similarly, the outer concentric tube (14) has a first end (34) with a fluid flow inlet (36) for receiving an input (38) of an intake fluid flow and a second end (40) with a fluid flow outlet (42) for discharging the intake fluid (38). The exhaust fluid flows through the passageway of the inner concentric tube (12) in a direction substantially opposite to the intake fluid flow (38) through passageway formed by the outer concentric tube (14) of the heat exchanger arm (10).

[0026] Preferably, the heat exchanging arm (10) is adapted to be attached to an exterior portion (44) of the furnace (F).

[0027] The inner (12) and outer (14) concentric tubes in a preferred embodiment form rectangular channels (16 and 18) to maximize the surface area of the common walls (20) to increase available surface area for heat transfer.

[0028] Generally, the inner concentric tube (12) is formed from a first and a second sheet (46 and 48 respectively), with each sheet having a first and a second edge (50 and 52 respectively). The outer concentric tube (14) is also formed from a first and a second sheet (54 and 56 respectively) with each having a first and a second edge (58 and 60 respectively). The first edges (50, 58) of the first and second sheets of the inner concentric tube (12) and the first and second sheets of the outer concentric tube (14) are crimped together (62). Similarly, the second edges (52, 60) of the first and second sheets of the inner concentric tube (12) and the first and second sheets of the outer concentric tube (14) are crimped together (64) forming the channels (16, 18).

[0029] The longitudinal axes of the crimping of the sheets are in a direction substantially parallel to the fluid flow through the arm (10).

[0030] In a preferred embodiment the heat exchanger (E) has a plurality of arms (10) with their respective second ends 28, 40) joined at a heat exchanger hub (66). The heat

exchanger hub (66) has an exhaust fluid intake (30) shared by the joined arms (10).

[0031] Referring to Figures 4 and 5, in another embodiment the heat exchanger (E) can be reduced to one or more horseshoe or U shaped arms with the same cross section shown in Figure 3. In this embodiment the ease of manufacturing is considerably improved, but at the expense of a larger resulting oven and heat exchanger assembly. With this configuration, a manifold section is not required.

[0032] An optional mounting flange (70) can be used to attach or mount the U or J shape arms. Further, the arms may be formed with ends (72 and 74) to assist in connection of the heat exchanger (E).

[0033] The present counter-flow heat exchanger (E) using narrow rectangular channels optionally includes a common central "manifold" section (66) on the top and three perpendicular legs (10) using the narrow rectangular channel geometry (see Figure 1). The geometry of the present heat exchanger is such that it easily integrates with a gas generating furnace (see Figure 2) or a fuel cell.

[0034] The narrow flow channels take up a small amount of radial space on the exterior of the furnace, but provide a large area for heat transfer between the two passes. A cross-section of the heat exchanger flow channel is shown in Figure 3.

[0035] The present heat exchanger (E) is preferably fabricated entirely from stainless steel sheet stamped parts. The seams are rolled and crimped to seal the flow passages in a way similar to that used for some residential furnace heat exchangers. Other means such as welding could also be used to seal these flow passages. Significant advantages to this heat exchanger (E) design are the relatively low cost and low weight.

[0036] The present heat exchanger (E) can be fabricated from other materials that are suitable for the elevated temperature and fluid or gaseous environment of common usage.

[0037] Axial heat conduction losses are minimized by the use of a low thermal conductivity material (austenitic stainless steel) and by using the minimum practical material thickness. Use of a relatively thin wall (20) between the flow passes also helps

to minimize the resistance to heat flow between them. Heat loss to the environment is reduced by running the hotter of the two flow streams (the furnace exhaust) down the center channel with the colder, inlet air, stream surrounding it (see Figure 3). In addition to these features, high resistance thermal insulation (68) may be applied to the exterior surfaces to reduce heat loss to the environment.

[0038] Tests of the heat exchanger (E) of the present invention using various heat transfer augmentation techniques have demonstrated that improved thermal effectiveness is achieved.

[0039] The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction may be made without departing from the spirit of the invention.